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WEAK-FORM EFFICIENCY IN THE GOLD MARKET*

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Adrian E. Tschoegl

WP1013-78 August 1978

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ABSTRACT

This paper investigates the efficiency of the gold market with respect to the information contained in sequences of successive price changes. Tests for serial correlation and modelling the changes as first-order Markov processes indicate some short-term dependence. While there is no reason to believe outsiders can profit from knowledge of these relationships, insiders might, though this is not certain. In addition, the application of a market model to monthly returns for the period 1974-1977 results in the finding that gold's 'alpha' and 'beta' were positive, but not significantly different from zero.

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Weak-Form Efficiency in the Gold Market

I. Introduction

This paper treats gold as a financial asset and investigates its price from the point of view of the Efficient Markets Hypothesis(EMH). The strong form of the EMH proposes that all information will be impounded in security prices in such a way as to leave no opportunity for extraordinary returns based on any information. One logical way to begin research into the degree to which this formulation holds is to take some extremely simple, widely available item of information and to see whether one can use it for profitable trading. If the market is inefficient with respect to simple information it is extremely improbable that it would be efficient with respect to some which is more complex or less freely available.

The paper examines a series of twice-daily prices for gold to determine whether successive price changes are independent, and if not, whether one can use knowledge of the dependence to generate trading profits. The techniques used are tests for serial correlation and modelling the change sequences as first-order Markov processes.

The paper also applies a standard one-factor market model to monthly returns on gold. This is an amorphous test in that it simply checks if over some period holders of gold achieved excess risk-adjusted returns

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on their investment. In an efficient market the ex ante expected excess risk-adjusted return is zero. One can, however, only observe ex post realizations. Thus while the tests prove nothing, grossly discrepant results would cause one to question either market efficiency or the model.

Academic research in the field of finance has by-and-large ignored gold.International finance as a sub-field of economics has of course discussed it in the context of international reserves and balance of payments considerations. However while there are innumerable articles investigating the efficiency of the US, UK, W.German, French, Spanish, Japanese, and Israeli stockmarkets, and the market for foreign exchange, there is no comparable study of the gold market. This is probably due in large part to the fact that from 1933 to 1974 Americans were legally forbidden to hold gold in any form other than as jewelry or coins of numismatic value. In a sense it dropped from view. There are a number of reasons the gold market might be of interest.

First, it represents a substantial and probably highly efficient financial asset market. Pick (1977) estimates that at the end of 1976 the value of the stocks of gold held by governments and international organizations was in the vicinity of US$203.7 billion and that of private holdings US$104.9 billion (both amounts based on a free-market price of US$135/oz.). This compares with a capitalization for the New York Stock Exchange of US$856 billion, and US$65 billion for the London Stock Exchange (Capital International Perspective, Jan. 1977).

There are major gold markets in Zurich , London, Frankfurt,Paris, New York, Chicago, Hong Kong, and Singapore. Informal, and often illegal, markets in most of the world's countries augment the main trading centers. One would therefore expect the gold market to be highly efficient: trading is potentially almost continuous and competition between markets should reduce the commissions and transaction costs in any one market. The widely dispersed markets not only increase the overall market's liquidity, but also act as sensors so that information arising anywhere can very quickly begin to influence prices . Thus the gold market enables one to test the theory of efficient markets in a market in which it was not developed, but where a priori one would expect it to hold.

The second reason gold might be of interest is related to but opposed to the first. While one would expect the market to be highly efficient for the reasons listed above, nevertheless gold is popularly associated with hoarding, 'gold bugs', and apocalyptic visions of the future. Its price might therefore reflect 'mispricing' (in the sense of a negative risk-adjusted excess return), if buyers pay a premium because of gold's value to them as a hedge against the complete collapse of national political and monetary systems, or because, being in 'bearer' form, it enables them to evade taxes or confiscation.

The third reason is a technical one. The London morning and afternoon gold price fixings give the researcher ready access to two transactions prices per day. At 10:30am and 3:30pm each business day, representatives of the five firms that form the London gold market meet

and shortly thereafter fix a price that clears the market. The fixings price series are therefore relatively uncontaminated by the inclusion of prices carried over from some earlier transaction. The data does suffer from some problems since the times are not exact and the volumes traded are secret. Even if the volumes traded were known, these would represent approximations since the firms offset many buy and sell orders internally and only clear their imbalances. This last fact however makes it reasonably certain that even if no gold is traded at any particular fixing, the price is still a transaction price since the firms will use it in matching some orders internally. Finally, gold holdings do not receive dividend payments. Therefore we can be fairly confident that any signs of non-independence between successive price changes that we find, especially in day-to-day data, is due to real phenomena and is not an artefact of the way prices are recorded or dividends attributed.

The basic model used is as follows:

$$Z'(t) = (P'(t) - P(t-1))/P(t-1) = r(t) + e'(t)$$

where $Z'(t)$ is the percentage return on gold over the period t-1 to t, $P(t)$ is the price of gold at time t, $r(t)$ is the normal rate of return on assets of the same risk and $e'(t)$ is the unexpected component of the return. The prime indicates a random variable as of time t-1. $e'(t)$ is assumed to have the properties:

$E[e'(t)] = 0$

$\text{cov}\ (e'(t), e'(t-k)) = 0,\ t = 1,2,\ldots k,\ k<t$

If $r(t)$ is a constant then

$E[Z'(T)] = E[r(t) + e'(t)]$

$= r(t)$

and therefore $\text{cov}\ (Z'(t),Z'(t-k)) = 0.$

This further implies that:

$E[Z'(t)] = E[Z'(t)|Z(t-1), Z(t-2)\ldots\ Z(t-k)]$

that is, the marginal and conditional returns are equal, or that knowledge of the past series of returns provides no information about the expected return over the next period that is not already incorporated in the return. Since the covariance of the returns equals zero, this implies that the correlation between $Z'(t)$ and $Z(t-k)$ equals zero. However suppose that $r(t)$ is not a constant but rather a function of other variables which change over time. If the market knows the relationship, the unexpected portion of the return may still follow the model:

$E[e'(t)] = 0$

$$cov(e'(t),e'(t-1)) = 0$$

and,

$$E[Z'(t)|Z(t-1),Z(t-2),...Z(t-k)] = r(t)$$

but,

$$E[Z'(t)|Z(t-1),Z(t-2),...,Z(t-k)] \neq E[Z'(T)],$$

except by chance, and similarly,

$$cov(Z'(t),Z'(t-k)) \neq 0$$

This means that the expectation of the next period's return depends on the past series of returns, the serial correlation of the returns is not equal to zero, but no consistent excess returns are possible since prices already fully incorporate the relevant information. Thus if r(t) is not constant, the presence of serial correlation in the returns does not prove market inefficiency. However if r(t) is small and furthermore the period over which one measures it is short, then one can treat it as constant, and assume

$$cov(Z'(t),Z'(t-k)) \simeq 0.$$

The presence of serial correlation in the returns then remains as an

indicator that the market may be inefficient with respect to the information contained in the return series.

In Section II we report the means and standard deviations of several returns series. Section III presents the results of tests for serial correlation. Section IV takes the two series with the largest first-order serial correlation and models them as first-order Markov processes. Section V applies a standard market model to four years of monthly returns. Section VI summarizes the results.

Section II. Distributions

The data consist of the morning (AM) and afternoon (PM) fixing prices in London from Jan. 2, 1975 to Jun. 30, 1977. There were 631 observations in the AM series and 629 in the PM. Two prices were interpolated for the PM fix for Dec 24, 1975 and 1976 to bring both series to the same length. Over the period the price of gold fell from US$185/troy ounce at the begining of the period to US$143/troy ounce at the end. The AM and PM series were used to generate four series of the form:

$$Z(t) = P(t)/P(t-1) - 1$$

and four series of absolute changes:

$$A(t) = P(t) - P(t-1)$$

The four series represent:a) the within-day change (morning to afternoon): b) the overnight change (afternoon to subsequent morning): c) the morning-to-morning change: and d), the afternoon-to-afternoon change. Table I presents their means and standard deviations.

While the means for all eight are negative, none are significantly different from zero at the 90% confidence level. This indicates that over very short periods anticipated changes are completely swamped by the effect of the unanticipated changes. One would not reject the hypothesis that $E[r(t)+e(t)]=0$, and one cannot infer that $E[r(t)]<0$. Histograms and Gaussian probability plots all show the distributions of the changes to be lepto-kurtotic. They are more peaked than the Gaussian, and have fatter tails. These results are consistent with Mandelbrots' (1965) and Fama's (1965) findings for cotton and stock price changes respectively. We will not in this paper enter the debate on the nature of the generating processes since this is not essential for our purposes.

Section III. Serial Correlations

Even if the distributions of the price changes do not have a finite variance, the serial correlation coefficient (RHO) is still an unbiased estimate of the true serial correlation (Fama, 1965, from some results of Wise, 1964). In view of the questions concerning the appropriate distribution and the constancy of r(t), the RHOs reported below are only indicative. Nevertheless, the discovery of strongly

TABLE I

MEANS AND STANDARD DEVIATIONS

Variable	Description	Mean	Standard Deviation
A4	PM(t) - AM(t)	$-0.018	$0.952
A20	AM(t) - PM(t-1)	$-0.048	$1.299
Aam	AM(t) - AM(t-1)	$-0.0687	$1.652
Apm	PM(t) - PM(t-1)	$-0.051	$1.711
Z4	PM(t)/AM(t) - 1	-0.00007%	.0066%
Z20	AM(t)/PM(t-1) - 1	-0.00027%	.0093%
Zam	AM(t)/AM(t-1) - 1	-0.00034%	.0118%
Zpm	PM(t)/PM(t-1) - 1	-0.00024%	.0123%

N = 630

significant serial correlation coefficients would leave us uncomfortable about our hypothesis of the independence of the unexpected component of successive price changes.

In that vein we have calculated RHOs for four sets of successsive changes. Asterisks indicate significance at the 5% level.

a)Z20(t) and Z4(t)

RHO = .208*

The change from the evening to the following morning is strongly and positively related to the subsequent morning to afternoon change.

b) Z4(t) and Z20(t+1)

RHO = .061

The within-the-day change is positively and weakly related to the following over-night change.

c) Zam(t-1) and Zam(t)

RHO = -.034

The morning-to-morning change is negatively and weakly related to the previous morning-to-morning change.

d) Zpm(t-1) and Zpm (t)

RHO = -.099*

The afternoon-to-afternoon change tends to reverse the previous afternoon-to-afternoon change.

Two of the four RHOs are significant, indicating some lack of independence between successive changes. However the standard errors of the RHOs were estimated by the expression: $\sqrt{(1/n-1)}$. As Fama (1972) notes, if the distributions of returns are 'fat-tailed' rather than Gaussian, this method results in an overstatement of the significance. In addition, the two day-to-day series both have negative first-order serial correlation coefficients, whereas the two sets of changes over shorter periods both have positive first-order RHOs.

Niederhoffer and Osborne (1966) argue that in markets with market-makers, a sequence of orders will generate reversals (i.e. RHO < 0) when buy and sell orders are equally numerous, and will generate continuations (RHO > 0) when one type of order predominates. The underlying economic mechanism involves the exhaustion of limit orders which form a 'reflecting barrier' when buy and sell orders are roughly in balance. Our results are consistent with this argument, especially when one supplements it with the possibility that the morning fixing is less important than the afternoon one. Each fixing price then is an

outcome of two opposing tendencies: one to continuation in the short run, and the other to reversal over the longer periods. Over longer intervals prices are more likely to have adjusted to reflect fully new information and by the afternoon fixing in particular buy and sell orders are likely to be present in equal proportion. Hence for the afternoon-to-afternoon series reversals dominate continuations, and there is only weak continuation from the within-the-day change to the overnight change. If the morning fixing is less important than the afternoon it will not completely adjust to new information occurring late in the previous afternoon and overnight. The very strong tendency to continuation from the overnight change to the within- the-day change will then almost match the tendency to reversals due to the longer elapsed period between morning-to-morning changes.

This explanation depends strongly on the assumption that the morning fixing on average represents a smaller volume of trading than does the afternoon. The assumption however is not unreasonable if one remembers that 10:30am in London is 7:30am in New York and 6:30am in Chicago, and that since 1974 these have become increasingly important gold markets.

Table II presents the serial correlation coefficients for the two day-to-day series with lags of from 1 to 60 trading days. The RHOs for the daily changes seem random and to damp-out over time. In fact, we cannot reject (at the 5% significance level) the null hypothesis that the auto-correlation function for the lags of 1 to 10 days is flat and equal to zero. The Q statistics for Zam and Zpm are 14.96 and 17.03 respectively, with the latter being significant at the 10% significance

TABLE II

SERIAL CORRELATION COEFFICIENTS

Variable \ Lag	1	2	3	4	5	6	7	8	9	10	15	20	40	60
Zam	-.034	.004	.050	.097*	-.080*	-.067	.019	.009	-.016	-.005	.012	-.126*	-.048	0.13
Zpm	-.099*	-.027	.084*	.013	.045	-.075	-.030	.023	-.014	.001	.084*	-.069	-.002	.031

Asterisks indicate significance at the 5% level

level, where

$$Q = n \sum_j (RHO(j))^{**}2$$

and is distributed as chi-square with j degrees of freedom. RHO(j) is the serial correlation coefficient of lag j, (j=1,...,10), and n is the the number of observations. While the Q statistics are high, one must remember that the significance is exaggerated because of the fat-tailed distributions of the daily returns (Cornell & Dietrich, 1978). The magnitudes of the serial correlation coefficients of the lagged changes and of the Q statistics in this study are quite similar to those found by the authors just cited in their study of efficiency in the market for foreign exchange. There is one surprisingly large relation in the gold data between the morning-to-morning changes twenty days apart but this could easily be due to chance. While the results do not rule out more complex trading strategies than taking advantage of day-to-day dependence, no simple rules spring to mind. We will defer to later in the next Section the question of whether we can use the short-term dependence we have found to make extraordinary profits.

Section IV. Markov Transition Probabilities

An alternative approach to the use of serial correlations to investigate successive price changes is to model the changes as a

Markov process. Doing so requires no assumptions as to the nature of the distribution of the changes.

A number of authors have used this technique. In particular, Niederhoffer and Osborne(1966) investigated stock prices in the US, as did Fielitz(1975), and Fielitz and Bhargava(1973). Dryden(1969) and Ryan(1973) did the same for the United Kingdom, the first for the overall market index, and the latter for a sample of stocks quoted on the London exchange. The interested reader is referred to these works for a fuller description of the underlying mathematics and some of the further potentialities of this line of analysis, and to Anderson and Goodman (1957) for the derivation of the tests used below.

Markov theory is concerned with the transition of a system from one state to another. Any Markov Process is completely described by its Transition Probability Matrix(TPM). The TPM is a matrix of conditional probabilities. The horizontal dimension of the matrix is given by the states of the process at time (t), and the vertical by the states at time (t-1). The elements are estimates of the probability that the process will be in state j in a given period, given that it was in state i in the previous period. For a discrete, stationary Markov chain X(t), (t=0,1,...,T), with a finite number of states, the process is first-order Markov if

$$Pr[x(t) = s(j) | x(t-1) = s(i)] = Pr[x(t) = s(j) | x(t-1)=s(i), x(t-2)=s(i), \ldots x(t-k) = s(i)]$$

That is, the probability that x(t) is in state j at time (t) depends only on which state it was in at time (t-1) and not on the sequence of states prior to (t-1). The transition probabilities Pij satisfy the following conditions:

$$Pr[X(t) = s(j) | X(t-1) = s(i)] = Pij(t) = Pij(t+1) = Pij$$

for all T, with (i,j = 1.2,...,m), $0 \leq Pij \leq 1$, and $\Sigma j \; Pij = 1$, (j=1,2,...,k).

Anderson and Goodman (1957) have shown that the Maximum Likelihood Estimator of Pij is:

$$Pij = n(ij)/n(i)'$$

Where n(ij) is the number of observations in a cell,and $n(i)' = \Sigma j \; n(ij)$ or the total number of observations in the ith row. In this paper we have classified all price changes into one of three states: up (U), no change (NC), and down (D), defined by the percentage change being greater than, equal to, or less than zero respectively. We assume that the direction of the most recent change depends only on the direction of the preceeding change. We then test the assumption against the null hypothesis that successive changes are independent. We also test whether the results we observe are stationary over the sample period or not.

We prepared Transition Probability Matrices for the two sets of changes

with significant serial correlation coefficients. Table III presents the results for the sequence Z20(t) and Z4(t), and Table IV those for Zpm(t-1) and Zpm(t).

As one can see, in Table III continuations (an up followed by an up, etc.) are more probable than reversals (an up followed by a down, and vice-versa), which is consistent with the positive serial correlation coefficients observed earlier. In Table IV reversals are more likely than continuations, and this too is consistent with the series' RHO. In both tables continuations are almost as likely as reversals and this stands in some contrast to Niederhoffer and Osborne's findings that reversals were twice as likely as continuations. Their data however covered much shorter trading intervals than does this study.

The test of the null hypothesis that all the rows are identical is from Anderson and Goodman. The statistic:

$$\Sigma ij\ n(i)' \cdot (Pij - P'j)^2 / P'j$$

is distributed as chi-square with m(m-1) degrees of freedom, where m is the number of states of the process (i.e. m=3 in this case), and $P'j=\Sigma i\ n(ij)/\Sigma i\ \Sigma j\ n(ij)$ (i.e. the total number of observations in the jth column divided by the total number of observations). For Table III the results are X**2=20.809 with six degrees of freedom which is significant at the 1% level. For Table IV, X**2=13.2749 and is significant at the 5% level, but not at the 2.5% level. Thus we would reject the null hypothesis that the within-the-day change is

TABLE III

MARKOV TRANSITION PROBABILITY MATRIX

OVER-NIGHT CHANGE AND WITHIN-THE-DAY CHANGE

Z4

Z20	U	NC	D	Row Totals
U	157 / .58	23 / .08	93 / .34	273
NC	13 / .42	3 / .10	15 / .48	31
D	131 / .40	29 / .09	166 / .51	326
Column Totals	301 / .48	55 / .09	274 / .43	630

Note: Above diagonal elements are actual counts. Below diagonal elements are probabilities and sum to 1 across rows, except for rounding error.

TABLE IV

MARKOV TRANSITION PROBABILITY MATRIX

EVENING-TO-EVENING CHANGE AND SUBSEQUENT EVENING-TO-EVENING CHANGE

Zpm(t)

m(t-1)	U	NC	D	Row Totals
U	123 / .42	9 / .03	159 / .55	291
NC	5 / .24	2 / .10	14 / .66	21
D	164 / .52	10 / .03	143 / .45	317
Column Totals	292 / .46	21 / .03	316 / .50	629

Note: Above diagonal elements are actual counts. Below diagonal elements are probabilities and sum to 1 across rows, except for rounding error.

independent of the overnight change, but would be much more ambivalent about dependence between successive evening-to-evening changes.

We also tested whether or not these relations were stable over the sample period. The series were divided into five six-month periods. The relevant test statistic is similar to the one above, except that the P'(j) are replaced by P''(ij) where P''(ij) are the cell probabilities based on the entire sample, and the summation is over i,j, and t (T=1,...,5). The statistic is distributed as X**2 with m(m-1)(t-1) degrees of freedom. For the series Z20(t) and Z4(t), X**2=14.1351 which is not significant at the 5% level. For the series Zpm(t-1) and Zpm(t), X**2=21.263 which also is not significant at the 5% level. Thus in both cases we would not reject the null hypothesis that the processes were stable over the sample period.

The next question of course is whether one can use the dependence evidenced in Table III for profitable trading. To test this we derived the means and variances for Z4(t), conditional on knowing the state of Z20(t-1).

1) $E[Z4 \mid Z20 > 0] = .13\%$, with a standard deviation of .55%

2) $E[Z4 \mid Z20 = 0] = -.033\%$, with a standard deviation of .63%

3) $E[Z4 \mid Z20 < 0] = -.1\%$, with a standard deviation of .66%

Green (1968) reports that the commission charged on a purchase or sale

conducted via the fixing was .00025%. While this may have changed, the implication is that if one could buy or sell at the fixing prices, one could make a profit, albeit with some risk. However to use this strategy one must know the fixing price and make one's decision before it is set. Purchases or sales outside of the fixing are subject to the normal bid/ask spreads. For the sample period this spread seems to have been on the order of .5 to 1.1%. Outsiders thus would seem to have been unable to make consistent profits from betting the transition probabilities of the most dependent sequence of changes.

On the other hand, this may not hold for insiders. Traders at a fixing are in telephone contact with their parent organizations who in turn are in contact with traders in Zurich, New York, etc. All these individuals therefore do have some idea of what state will prevail, and may be able to conduct their transactions at the fixing commissions. However we do not know what price elasticities pertain. Very small changes in the quantities of gold offered might move prices sufficiently to severely limit potential profits. Finally, the profits may be no more than is required to compensate traders for the time, telephone bills, and similar costs that they incur in policing the price.

The results from modeling gold price changes as a first-order Markov process are similar to those of the authors cited at the beginning of the Section. All have found some tendency to non-independence between successive price changes. In general though the tendency seems to be inversely related to the size of the company whose stock is being

examined. Fielitz(1975) also found that the dependency tended not to be stable over time.

Section V. Market Model

This section reports the results from applying a one-factor market model to four years of monthly returns on gold. The purpose of the exercise was two-fold: first, to estimate gold's 'beta', i.e. its systematic risk to see whether this was negative as has been suggested by some (e.g. MacDonald & Solnik, 1977) and second, to estimate its ex post risk-adjusted excess return.

The market model is a standard one as used for instance by Jensen(1968):

$$Rg - Rf = a + b(Rm - Rf) + e$$

where Rg,Rm, and Rf are the returns on gold, a market portfolio, and the riskless asset respectively, (b) is the measure of gold's systematic risk i.e. the ratio of its covariance with the market portfolio divided by the variance of the latter, (a) is the Jensen measure of the excess return, and (e) is the classical stochastic error term.

The perspective of the test is that of a US investor who can construct

a portfolio by choosing from amongst gold, Treasury Bills, and a world market portfolio, all of which are denominated in US dollars. The test period is from January 1974 to December 1977. The returns on gold are calculated from the PM fixing price on the last trading day of the month. The proxy for the riskless asset is the one-month T-bill rate. For the world market portfolio we have used Capital International Perspective's World Market Index. This is a market-value weighted index based on indexes of the eighteen largest stock markets of the world. The national market indexes are also market-value weighted portfolios of stocks, but converted to US$ at current exchange rates.

We also used two different ways of calculating the return on gold and the market:

a) $Rg = P(t)/P(t-1) - 1$

$Rm = \text{Index}(t)/\text{Index}(t-1) - 1 + \text{Dividends}$

b) $Rg = \ln(P(t)) - \ln(P(t-1))$

$Rm = \ln(\text{Index}(t)) - \ln(\text{Index}(t-1)) + \text{Dividends}$

The reason for doing this was to take into account to some degree the mis-specification of the investment horizon. Thus the second regression gives the more accurate estimate of (b), but biases (a) downward. This situation reverses for the first model.

The regression results were (with t-statistics in parentheses):

a) $Rg - Rf = 0.00539 + 0.02765(Rm - Rf)$

$(0.5439) \quad (0.1272)$

$\bar{R}2 = -0.02138$ SER $= 0.0685$ DW $= 1.25$ F(1/46)$= 0.0162$

b) $Rg - Rf = 0.00321 + 0.03135(Rm - Rf)$

$(0.3338) \quad (0.1467)$

$\bar{R}2 = -0.02126$ SER $= 0.0665$ DW $= 1.30$ F(1/46) $= 0.0215$

In neither regression are the coefficients significant at even the 40% significance level, and the F-tests are similarly weak. One would clearly have to reach to reject the null hypothesis that all the coefficients were equal to zero.

The positive, albeit insignificantly different from zero, (b) for gold may surprise some readers. There has been a general feeling that gold might have a negative correlation with the market. MacDonald & Solnik (1977) for instance, found a correlation of -0.07 between percentage changes in the gold price and the Standard & Poors Composite Index over the period 1971 to 1976. One must remember though that around early to mid-1973 the collapse of the Smithsonian agreement resulted in the floating of the major world currencies. The prices of both gold and the market portfolio are determined in world markets. Therefore the effect of exchange rate changes impart some positive correlation to the US$ values of both.

The results for the intercept term (a) are not consistent with those

of Black, Jensen, & Scholes (1972) who found that in three out of four sub-periods that their zero-beta portfolios had intercepts significantly greater than zero. However the results are consistent with Hughes, Logue, & Sweeney(1975). These authors found that when betas were computed using a domestic market index, Multinational Companies' risk-adjusted performance exceeded that of domestic firms. When the betas were computed using a world index though, the performance of the two sets of companies were quite similar. Hughes, et al., argued that their results lent credence to the notion that financial assets are priced internationally and that this in turn implies that financial markets are integrated internationally.

Gold is pre-eminently an international asset so it is perhaps not surprising that it should have been correctly priced in the sense that the risk-adjusted excess return ex post was insignificantly different from zero. In any case one might expect that it should be positive merely because investors wish to earn a normal return net of storage costs. These are minimal though (on the order of 0.1% / annum). It is still possible that ex ante gold had a negative expected excess risk-adjusted return because of buying by investors willing to pay a premium for its special services, but that later developments awarded them an unexpected offsetting bonus. We can neither confirm nor reject this possibility. The most likely explanations for the positive (a) however remain chance, and/or missing factors.

Section VI. Summary

This paper has investigated the efficiency of the gold market primarily with respect to the information contained in sequences of successive price changes. Both tests for serial correlation and modelling the changes as first-order Markov processes indicated some short-term dependence. There was no reason to believe though that outsiders could profit from knowledge of these relationships. Market makers and professional traders might, but it is not clear that they can do so in excess of their costs.

The application of a standard market model to monthly returns revealed that for the period 1974-1977, the covariance of the return on gold in excess of the riskless rate with that of the market was positive, but not significantly different from zero. Similarly, the excess risk-adjusted return was also positive, but not significantly different from zero.

Further research might proceed in the direction of investigating the market's efficiency with respect to more complex models of the time series of price changes, structural models of price formation, and publicly available information. At this point though there is no reason to suspect that the gold market in general is any less efficient than any other international asset market.

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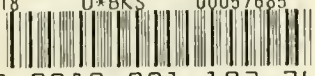
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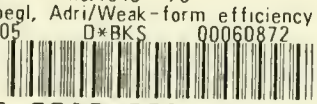
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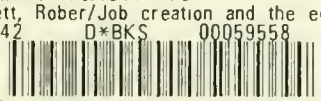
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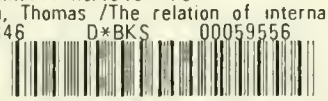
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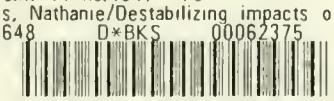
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